

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Jackie Y. Ying et al.
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For: NANOCRYSTALLINE APATITES AND COMPOSITES, PROSTHESES
INCORPORATING THEM, AND METHOD FOR THEIR PRODUCTION

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Sir:

PRELIMINARY AMENDMENT

Before beginning examination of the above-identified application on its merits, please amend the application as follows:

IN THE CLAIMS

Please add the following claims:

45. (New) A method, comprising:

providing a composition comprising apatite particles having a dimension of less than about 1 μm and a surface area of at least about 40 m^2/g ; and

sintering the composition to form a densified apatite structure having an average XRD crystal size of less than about 250 nm, a density of at least about 98%, and a compressive strength of at least about 500 MPa, wherein the densified apatite structure undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 $^{\circ}\text{C}$ for at least about 2 hours.

46. (New) The method of claim 45, wherein the particles have a dimension of less than about 500 nm.

47. (New) The method of claim 46, wherein the particles have a dimension of less than about 250 nm.

48. (New) The method of claim 45, wherein the average XRD crystal size is less than about 150 nm.
49. (New) The method of claim 48, wherein the average XRD crystal size is less than about 100 nm.
50. (New) The method of claim 49, wherein the average XRD crystal size is less than about 50 nm.
51. (New) The method of claim 50, wherein the average XRD crystal size is less than about 30 nm.
52. (New) The method of claim 51, wherein the average XRD crystal size is less than about 20 nm.
53. (New) The method of claim 45, wherein the average compressive strength is at least about 700 MPa.
54. (New) The method of claim 45, wherein the phase decomposition is less than about 5%.
55. (New) The method of claim 54, wherein the phase decomposition is less than about 3%.
56. (New) The method of claim 45, wherein the densified apatite structure has a porosity of at least about 20%.
57. (New) The method of claim 56, wherein the densified apatite structure has a porosity of at least about 30%.
58. (New) The method of claim 57, wherein the densified apatite structure has a porosity of at least about 50%.

59. (New) The method of claim 58, wherein the densified apatite structure has a porosity of at least about 70%.
60. (New) The method of claim 45, wherein the apatite particles have a crystal size of less than about 1 μm .
61. (New) The method of claim 60, wherein the apatite particles have a surface area of at least about 60 m^2/g .
62. (New) The method of claim 61, wherein the apatite particles have a surface area of at least about 100 m^2/g .
63. (New) The method of claim 62, wherein the apatite particles have a surface area of at least about 150 m^2/g .
64. (New) The method of claim 45, wherein the densified apatite structure is a prosthesis.
65. (New) The method of claim 45, wherein the densified apatite structure is at least part of a prosthesis.
66. (New) The method of claim 45, wherein the densified apatite structure comprises an exterior coating on a prosthesis.
67. (New) The method of claim 66, wherein the coating has a thickness of at least about 0.5 μm .
68. (New) The method of claim 45, wherein the densified apatite structure comprises an auxiliary structural additive.

69. (New) A method as in claim 68, wherein the auxiliary structural additive comprises a ceramic additive.
70. (New) A method as in claim 68, wherein the auxiliary structural additive comprises a metal oxide.
71. (New) A method as in claim 70, wherein the metal oxide is selected from the group consisting of zirconia, titania, alumina, and alloys thereof.
72. (New) A method as in claim 68, wherein the auxiliary structural additive is a metal or alloy.
73. (New) A method as in claim 72, wherein the auxiliary structural additive is selected from the group consisting of Ti, Al, Ni, W, Fe, Mo, Co, Zr, V, and other structural metals and alloys thereof.
74. (New) A method as in claim 68, wherein the auxiliary structural additive is nanocrystalline.
75. (New) A method as in claim 68, wherein the auxiliary structural additive is added in an amount of between about 1% and about 50% by volume.
76. (New) A method as in claim 68, wherein the structural ceramic additive is added in an amount of from about 15% to about 35% by volume.
77. (New) The method of claim 45, wherein the densified apatite structure comprises zirconia.
78. (New) The method of claim 45, wherein the densified apatite structure comprises carbonated apatite.

79. (New) The method of claim 45, wherein the step of providing a composition comprises the step of precipitating the composition from a solution.
80. (New) A method as in claim 79, wherein the step of precipitation comprises adding a calcium salt to a phosphate source.
81. (New) A method as in claim 79, wherein the solution comprises a calcium salt at a concentration of less than about 1 M.
82. (New) A method as in claim 81, wherein the solution comprises a calcium salt at a concentration of less than about 0.5 M.
83. (New) A method as in claim 79, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 2.1 M.
84. (New) A method as in claim 83, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 0.21 M.
85. (New) A method as in claim 79, wherein the solution comprises a calcium salt and a phosphate source in a molar ratio of about 10:6.
86. (New) A method as in claim 79, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
87. (New) A method as in claim 86, wherein the step of precipitating comprises adding a calcium source to a phosphate source at a rate of less than about 0.010 mol of calcium source per minute.
88. (New) A method as in claim 87, wherein the adding rate is less than about 0.007 mol calcium source per minute.

89. (New) A method as in claim 88, wherein the adding rate is less than about 0.005 mol calcium source per minute.
90. (New) A method as in claim 86, wherein the calcium source comprises CaNO_3 .
91. (New) A method as in claim 86, wherein the phosphate source comprises $(\text{NH}_4)_2\text{HPO}_4$.
92. (New) A method as in claim 79, wherein the solution has a pH of between about 7 and about 14.
93. (New) A method as in claim 92, wherein the solution has a pH of between about 11 and about 13.
94. (New) A method as in claim 45, further comprising the step of aging the composition at a temperature of between about -25°C and about 100°C .
95. (New) A method as in claim 94, wherein the temperature is between about 10°C and about 50°C .
96. (New) A method as in claim 95, wherein the temperature is about 20°C .
97. (New) A method as in claim 45, further comprising the step of aging the composition for at least about 1 minute.
98. (New) A method as in claim 45, further comprising the step of calcining the composition at a temperature of less than about 1000°C .
99. (New) A method as in claim 45, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
100. (New) A method as in claim 99, wherein the phase decomposition is less than about 5%.

101. (New) A method as in claim 100, wherein the phase decomposition is less than about 3%.
102. (New) A method as in claim 45, wherein the sintering step occurs in the absence of sintering aids.
103. (New) The method of claim 45, wherein the sintering step is pressureless sintering.
104. (New) The method of claim 45, wherein the sintering step is pressure-assisted sintering.
105. (New) The method of claim 45, wherein the densified apatite structure is homogeneous.
106. (New) A method as in claim 45, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
107. (New) A method as in claim 106, wherein the sintering step occurs at a temperature of less than about 1100 °C.
108. (New) A method as in claim 106, wherein the sintering step occurs at a temperature of less than about 1000 °C.
109. (New) A method as in claim 107, wherein the sintering step occurs at a temperature of less than about 900 °C.
110. (New) The method of claim 60, wherein the apatite particles have a crystal size of less than about 500 nm.
111. (New) The method of claim 110, wherein the apatite particles have a crystal size of less than about 250 nm.

112. (New) An article, comprising:

a densified apatite structure having a dimension of at least about 0.5 cm and a compressive strength of at least about 500 MPa which undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

113. (New) The article of claim 112, wherein the densified apatite structure has an average crystal size of less than about 250 nm.

114. (New) The article of claim 113, wherein the average crystal size is less than about 150 nm.

115. (New) The article of claim 114, wherein the average crystal size is less than about 100 nm.

116. (New) The article of claim 115, wherein the average crystal size is less than about 50 nm.

117. (New) The article of claim 116, wherein the average crystal size is less than about 30 nm.

118. (New) The article of claim 117, wherein the average crystal size is less than about 20 nm.

119. (New) The article of claim 112, wherein the average compressive strength is at least about 700 MPa.

120. (New) The article of claim 112, wherein the phase decomposition is less than about 5%.

121. (New) The article of claim 120, wherein the phase decomposition is less than about 3%.

122. (New) The article of claim 112, wherein the densified apatite structure has a porosity of at least about 20%.
123. (New) The article of claim 122, wherein the densified apatite structure has a porosity of at least about 30%.
124. (New) The article of claim 123, wherein the densified apatite structure has a porosity of at least about 50%.
125. (New) The article of claim 124, wherein the densified apatite structure has a porosity of at least about 70%.
126. (New) The article of claim 112, wherein the densified apatite structure is a prosthesis.
127. (New) The article of claim 112, wherein the densified apatite structure is at least part of a prosthesis.
128. (New) The article of claim 112, wherein the densified apatite structure comprises an exterior coating on a prosthesis.
129. (New) The article of claim 128, wherein the coating has a thickness of at least about 0.5 μm .
130. (New) The article of claim 112, wherein the densified apatite structure comprises an auxiliary structural additive.
131. (New) A article as in claim 130, wherein the auxiliary structural additive comprises a ceramic additive.
132. (New) A article as in claim 130, wherein the auxiliary structural additive comprises a metal oxide.

133. (New) A article as in claim 132, wherein the metal oxide is selected from the group consisting of zirconia, titania, alumina, and alloys thereof.
134. (New) A article as in claim 130, wherein the auxiliary structural additive is a metal or alloy.
135. (New) A article as in claim 134, wherein the auxiliary structural additive is selected from the group consisting of Ti, Al, Ni, W, Fe, Mo, Co, Zr, V and other structural metals and alloys thereof.
136. (New) A article as in claim 130, wherein the auxiliary structural additive is nanocrystalline.
137. (New) A article as in claim 130, wherein the auxiliary structural additive is added in an amount of between about 1% and about 50% by volume.
138. (New) A article as in claim 130, wherein the structural ceramic additive is added in an amount of from about 15% to about 35% by volume.
139. (New) The article of claim 112, wherein the densified apatite structure comprises zirconia.
140. (New) The article of claim 112, wherein the densified apatite structure comprises carbonated apatite.
141. (New) The article of claim 112, wherein the densified apatite structure is formed from apatite particles having a dimension of less than about 1 μm .
142. (New) The article of claim 141, wherein the apatite particles have a dimension of less than about 500 nm.

143. (New) The article of claim 142, wherein the apatite particles have a dimension of less than about 250 nm.
144. (New) The article of claim 112, wherein the density of the densified apatite structure is greater than about 90%.
145. (New) The article of claim 144, wherein the density is greater than about 95%.
146. (New) The article of claim 145, wherein the density is greater than about 98%.
147. (New) The article of claim 112, wherein the densified apatite structure is formed from particulate apatite having a surface area of at least about 40 m²/g.
148. (New) The article of claim 147, wherein the surface area is at least about 60 m²/g.
149. (New) The article of claim 148, wherein the surface area is at least about 100 m²/g.
150. (New) The article of claim 149, wherein the surface area is at least about 150 m²/g.
151. (New) An article, comprising:
_____ a prosthesis having a dimension of at least about 0.5 cm, the prosthesis comprising apatite having an average XRD crystal size of less than about 250 nm which undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
152. (New) The article of claim 151, wherein the prosthesis has a compressive strength of at least about 150 MPa.
153. (New) The article of claim 151, wherein the prosthesis has a density of at least about 90%.

154. (New) The article of claim 151, wherein the prosthesis has a porosity of at least about 20%.
155. (New) An article, comprising:
a prosthesis having a dimension of at least about 0.5 cm and a density of at least about 98%, the prosthesis comprising apatite which undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
156. (New) The article of claim 155, wherein the prosthesis has a compressive strength of at least about 150 MPa.
157. (New) The article of claim 155, wherein the prosthesis has an average XRD crystal size of less than about 250 nm.
158. (New) The article of claim 155, wherein the prosthesis has a porosity of at least about 20%.
159. (New) A method, comprising:
precipitating apatite from a solution as an apatite precipitate, the apatite precipitate having an average dimension of less than about 1 μm ; and
densifying the apatite precipitate into a densified apatite structure having a crystal size of less than about 250 nm and a density of at least about 98%.
160. (New) A method as in claim 159, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
161. (New) A method as in claim 159, further comprising the step of calcining the composition at a temperature of less than about 1000 °C.

162. (New) A method as in claim 159, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
163. (New) A method as in claim 159, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
164. (New) An article, comprising:
an apatite structure having a dimension of at least about 0.5 cm, a density of at least about 98%, and an average XRD crystal size of less than about 250 nm which undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
165. (New) The article of claim 164, wherein the apatite structure has a compressive strength of at least about 150 MPa.
166. (New) The article of claim 164, wherein the apatite structure has a porosity of at least about 20%.
167. (New) An article, comprising:
a prosthesis having a dimension of at least about 0.5 cm and a density of at least about 98%, the prosthesis comprising apatite having an average XRD crystal size of less than about 250 nm.
168. (New) The article of claim 167, wherein the prosthesis has a compressive strength of at least about 150 MPa.
169. (New) The article of claim 167, wherein the prosthesis undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.

170. (New) The article of claim 167, wherein the prosthesis has a porosity of at least about 20%.
171. (New) A method, comprising:
providing a composition comprising an apatite; and
sintering the composition to form a densified apatite structure having a compressive strength of at least about 500 MPa, a density of at least about 98%, and an average XRD crystal size of less than about 250 nm, wherein the densified apatite structure undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
172. (New) The method of claim 171, wherein the step of providing a composition comprises the step of precipitating the composition from a solution.
173. (New) A method as in claim 172, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
174. (New) A method as in claim 171, further comprising the step of calcining the composition at a temperature of less than about 1000 °C.
175. (New) A method as in claim 171, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
176. (New) A method as in claim 171, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
177. (New) A method, comprising:
providing apatite particles having a dimension of less than about 1 μm ; and
sintering the apatite particles at a temperature of less than about 1100 °C to form a prosthesis having a dimension of at least about 0.5 cm and an average crystal size of less than about 250 nm.

178. (New) The method of claim 177, wherein the step of providing apatite particles comprises the step of precipitating the apatite particles from a solution.
179. (New) A method as in claim 178, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
180. (New) A method as in claim 177, further comprising the step of calcining the apatite particles at a temperature of less than about 1000 °C.
181. (New) A method as in claim 177, further comprising the step of allowing phase decomposition of less than about 10% in the prosthesis.
182. (New) A method as in claim 177, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
183. (New) A method, comprising:
providing apatite particles having a dimension of less than about 1 μm; and
sintering the apatite particles at a temperature of less than about 1100 °C to form a densified apatite structure having a density of at least about 98% and a grain size of less than about 250 nm.
184. (New) The method of claim 183, wherein the step of providing apatite particles comprises the step of precipitating the apatite particles from a solution.
185. (New) A method as in claim 184, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
186. (New) A method as in claim 183, further comprising the step of calcining the apatite particles at a temperature of less than about 1000 °C.

187. (New) A method as in claim 183, further comprising the step of allowing phase decomposition of less than about 10% in the prosthesis.
188. (New) A method as in claim 183, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
189. (New) The method of claim 183, wherein the apatite particles have a surface area of at least about 40 m²/g.
190. (New) The method of claim 183, wherein the apatite particles have a dimension of less than about 1 μm.
191. (New) An article, comprising:
an apatite structure having a dimension of at least about 0.5 cm, a density of at least about 98%, and an average XRD crystal size of less than about 250 nm.
192. (New) The article of claim 191, wherein the apatite structure has a compressive strength of at least about 150 MPa.
193. (New) The article of claim 191, wherein the apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
194. (New) The article of claim 191, wherein the apatite structure has a porosity of at least about 20%.
195. (New) An article, comprising:
an apatite structure having a dimension of at least about 0.5 cm and an average XRD crystal size of less than about 250 nm, wherein the apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

196. (New) The article of claim 195, wherein the apatite structure has a compressive strength of at least about 150 MPa.
197. (New) The article of claim 195, wherein the apatite structure has a density of at least about 90%.
198. (New) The article of claim 195, wherein the apatite structure has a porosity of at least about 20%.
199. (New) An article, comprising:
an apatite structure having a dimension of at least about 0.5 cm and a density of at least about 98%, wherein the apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
200. (New) The article of claim 199, wherein the apatite structure has a compressive strength of at least about 150 MPa.
201. (New) The article of claim 199, wherein the apatite structure has an average XRD crystal size of less than about 250 nm.
202. (New) The article of claim 199, wherein the apatite structure has a porosity of at least about 20%.
203. (New) A method, comprising:
providing apatite particles having a dimension of less than about 1 μm and a surface area of at least about 40 m^2/g ; and
sintering the particles at a temperature of less than about 1100 °C to produce a densified apatite structure having a density of at least about 98%.

204. (New) The method of claim 203, wherein the step of providing apatite particles comprises the step of precipitating apatite particles from a solution.
205. (New) A method as in claim 203, further comprising the step of calcining the apatite particles at a temperature of less than about 1000 °C.
206. (New) A method as in claim 203, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
207. (New) A method, comprising:
providing a composition comprising an apatite; and
sintering the composition at a temperature of less than about 1100 °C to form a densified apatite structure having an average XRD crystal size of less than about 150 nm.
208. (New) The method of claim 207, wherein the step of providing apatite particles comprises the step of precipitating apatite particles from a solution.
209. (New) A method as in claim 207, further comprising the step of calcining the apatite particles at a temperature of less than about 1000 °C.
210. (New) A method as in claim 207, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
211. (New) A method as in claim 207, wherein the average XRD crystal size is less than about 100 nm.
212. (New) The method of claim 211, wherein the average XRD crystal size is less than about 50 nm.
213. (New) The method of claim 211, wherein the average XRD crystal size is less than about 30 nm.

214. (New) The method of claim 211, wherein the average XRD crystal size is less than about 20 nm.
215. (New) The method of claim 207, wherein the sintering temperature is less than about 1000 °C.
216. (New) The method of claim 215, wherein the sintering temperature is less than about 900 °C.
217. (New) An article, comprising:
an apatite structure having a compressive strength of at least about 500 MPa,
wherein the apatite structure undergoes phase decomposition of less than about 10%
when exposed to conditions of at least about 1300 °C for at least about 2 hours.
218. (New) The article of claim 217, wherein the apatite structure has a dimension of at least about 0.5 cm.
219. (New) The article of claim 217, wherein the apatite structure has an average XRD crystal size of less than about 250 nm.
220. (New) The article of claim 217, wherein the apatite structure has a density of at least about 98%.
221. (New) The article of claim 217, wherein the apatite structure has a porosity of at least about 20%.
222. (New) An article as in claim 217, further comprising an auxiliary structural additive.
223. (New) An article as in claim 222, wherein the auxiliary structural additive comprises a ceramic additive.

224. (New) An article as in claim 222, wherein the auxiliary structural additive comprises a metal oxide.
225. (New) An article as in claim 224, wherein the metal oxide is selected from the group consisting of zirconia, titania, alumina, and alloys thereof.
226. (New) An article as in claim 222, wherein the auxiliary structural additive is a metal or alloy.
227. (New) An article as in claim 226, wherein the auxiliary structural additive is selected from the group consisting of Ti, Al, Ni, W, Fe, Mo, Co, Zr, V, and other structural metals and alloys thereof.
228. (New) An article as in claim 222, wherein the auxiliary structural additive is nanocrystalline.
229. (New) An article as in claim 222, wherein the auxiliary structural additive is added in an amount of between about 1% and about 50% by volume.
230. (New) An article as in claim 222, wherein the structural ceramic additive is added in an amount of from about 15% to about 35% by volume.
231. (New) A method, comprising:
precipitating an apatite from a solution; and
sintering the apatite to form an article having a density of at least 98%, an average crystal size of less than about 250 nm, and a compressive strength of at least about 150 MPa.
232. (New) The method of claim 231, further comprising the step of removing the solvent from the precipitated apatite.

233. (New) The method of claim 236, wherein the average XRD crystal size is less than about 30 nm.
234. (New) The method of claim 231, wherein the average XRD crystal size is less than about 150 nm.
235. (New) A method as in claim 234, wherein the average XRD crystal size is less than about 100 nm.
236. (New) A method as in claim 235, wherein the average XRD crystal size is less than about 50 nm.
237. (New) A method as in claim 231, wherein the precipitating step comprises adding a calcium salt to a phosphate source.
238. (New) A method as in claim 231, wherein the solution comprises a calcium salt at a concentration of less than about 1 M.
239. (New) A method as in claim 238, wherein the solution comprises a calcium salt at a concentration of less than about 0.5 M.
240. (New) A method as in claim 231, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 2.1 M.
241. (New) A method as in claim 240, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 0.21 M.
242. (New) A method as in claim 231, wherein the solution comprises a calcium salt and a phosphate source in a molar ratio of about 10:6.

243. (New) A method as in claim 231, wherein the precipitating step comprises mixing a calcium source and a phosphate source.
244. (New) A method as in claim 231, wherein the precipitating step comprises adding a calcium source to a phosphate source at a rate of less than about 0.010 mol of calcium source per minute.
245. (New) A method as in claim 244, wherein the adding rate is less than about 0.007 mol calcium source per minute.
246. (New) A method as in claim 245, wherein the adding rate is less than about 0.005 mol calcium source per minute.
247. (New) A method as in claim 237, wherein the calcium source comprises CaNO_3 .
248. (New) A method as in claim 237, wherein the phosphate source comprises $(\text{NH}_4)_2\text{HPO}_4$.
249. (New) A method as in claim 231, wherein the solution has a pH of between about 7 and about 14.
250. (New) A method as in claim 249, wherein the solution has a pH of between about 11 and about 13.
251. (New) A method as in claim 231, wherein the precipitated apatite has a crystal size of less than about 150 nm.
252. (New) A method as in claim 251, wherein the precipitated apatite has a crystal size of less than about 100 nm.
253. (New) A method as in claim 252, wherein the precipitated apatite has a crystal size of less than about 50 nm.

254. (New) A method as in claim 253, wherein the precipitated apatite has a crystal size of less than about 20 nm.
255. (New) A method as in claim 231, wherein the precipitated apatite has a surface area of at least about 40 m²/g.
256. (New) A method as in claim 255, wherein the precipitated apatite has a surface area of at least about 60 m²/g.
257. (New) A method as in claim 256, wherein the precipitated apatite has a surface area of at least about 100 m²/g.
258. (New) A method as in claim 257, wherein the precipitated apatite has a surface area of at least about 150 m²/g.
259. (New) A method as in claim 231, further comprising the step of wet grinding the apatite precipitate to form an apatite product.
260. (New) A method as in claim 231, further comprising the step of aging the precipitated apatite at a temperature of between about -25 °C and about 100 °C.
261. (New) A method as in claim 260 wherein the temperature is between about 10 °C and about 50 °C.
262. (New) A method as in claim 261 wherein the temperature is about 20 °C.
263. (New) A method as in claim 231, further comprising aging the precipitated apatite for at least about 1 minute.

264. (New) A method as in claim 231, further comprising calcining the precipitated apatite at a temperature of less than about 1000 °C.

265. (New) A method as in claim 231, wherein the sintering step occurs at a temperature of no more than about 1200 °C for a period of time of no more than about 2 hours.

266. (New) A method as in claim 265, wherein the sintering step occurs at a temperature of no more than about 1100 °C for a period of time of no more than about 2 hours.

267. (New) A method as in claim 266, wherein the sintering step occurs at a temperature of no more than about 1000 °C for a period of time of no more than about 2 hours.

268. (New) A method as in claim 267, wherein the sintering step occurs at a temperature of no more than about 900 °C for a period of time of no more than about 2 hours.

269. (New) A method as in claim 231, further comprising allowing phase decomposition of less than about 10% in the article.

270. (New) A method as in claim 269, wherein the phase decomposition is less than about 5%.

271. (New) A method as in claim 270, wherein the phase decomposition is less than about 3%.

272. (New) A method as in claim 231, wherein the sintering step occurs at a temperature of at least about 1000 °C for a period of time of at least about 2 hours while allowing phase decomposition of less than about 10% in the article.

273. (New) A method as in claim 272, wherein the temperature is of at least about 1100 °C.

274. (New) A method as in claim 231, wherein the sintering step occurs in the absence of sintering aids.
275. (New) A method as in claim 231, wherein the article has a dimension of at least about 0.5 cm.
276. (New) A method as in claim 231, wherein the solution comprises, in suspension, an auxiliary structural additive.
277. (New) The method of claim 276, wherein the article is a composite particulate apatite.
278. (New) The method of claim 276, wherein the article comprises particulate auxiliary structural additive.
279. (New) A method as in claim 231, wherein the precipitating step comprises essentially simultaneously co-precipitating the apatite and an auxiliary structural additive.
280. (New) A method as in claim 231, further comprising, following precipitation of an auxiliary structural additive, precipitating the apatite from solution.
281. (New) A method, comprising:
_____ providing a composition comprising an apatite; and
_____ pressure-assisted sintering the composition at a temperature of less than about 1100 °C to produce a densified apatite structure with a density of greater than about 98%.
282. (New) A method as in claim 281, further comprising the step of calcining the composition at a temperature of less than about 1000 °C.
283. (New) A method as in claim 281, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.

284. (New) The method of claim 281, wherein the pressure-assisted sintering occurs at a temperature of less than about 1000 °C.
285. (New) The method of claim 281, wherein the composition is sintered form a densified apatite structure having a compressive strength of at least about 150 MPa.
286. (New) The method of claim 281, wherein the sintered composition undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1100 °C for at least about 2 hours.
287. (New) A method as in claim 281, wherein the sintering step comprises sintering the composition in the presence of an auxiliary structural additive.
288. (New) A method, comprising:
_____ providing apatite particles having a dimension of less than about 1 μm and a surface area of at least about 40 m²/g; and
_____ sintering the apatite particles to form an apatite structure having a dimension of at least about 0.5 cm.
289. (New) The method of claim 288, wherein the sintering step comprises pressure-assisted sintering.
290. (New) The method of claim 288, wherein the sintering step comprises pressureless sintering.
291. (New) The method of claim 288, wherein the sintering step occurs in the absence of any sintering aids.
292. (New) The method of claim 288, wherein the apatite structure is homogeneous.

293. (New) The method of claim 288, wherein the apatite structure has a density of at least about 90%.
294. (New) A method as in claim 293, wherein the density is at least about 95%.
295. (New) A method as in claim 294, wherein the density is at least about 98%.
296. (New) A method as in claim 288, wherein the sintering step occurs at a temperature of no more than about 1300 °C.
297. (New) A method as in claim 296, wherein the temperature is no more than about 1200 °C.
298. (New) A method as in claim 297, wherein the temperature is no more than about 1100 °C.
299. (New) A method as in claim 298, wherein the temperature is no more than about 1000 °C.
300. (New) A method as in claim 299, wherein the temperature is no more than about 900 °C.
301. (New) A method as in claim 288, wherein the apatite structure has undergone apatite decomposition of less than about 10%.
302. (New) A method as in claim 301, wherein the apatite structure has undergone apatite decomposition of less than about 5%.
303. (New) A method as in claim 302, wherein the apatite structure has undergone apatite decomposition of less than about 3%.

304. (New) A method as in claim 288, wherein the sintering step comprises sintering the apatite particles in the presence of an auxiliary structural additive.
305. (New) A method, comprising:
providing apatite particles having a dimension of less than about 1 μm and a surface area of at least about 40 m^2/g ; and
sintering the apatite particles to form a densified apatite structure having a compressive strength of at least about 150 MPa.
206. (New) A method as in claim 305, wherein the sintering step comprises sintering the apatite particles in the presence of an auxiliary structural additive.
307. (New) The method of claim 305, wherein the step of providing apatite particles comprises the step of precipitating apatite particles from a solution.
308. (New) A method as in claim 307, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
309. (New) A method as in claim 307, further comprising the step of calcining the composition at a temperature of less than about 1000 $^{\circ}\text{C}$.
310. (New) A method as in claim 305, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.
311. (New) A method as in claim 305, wherein the sintering step occurs at a temperature of less than about 1200 $^{\circ}\text{C}$ for a period of time of at least about 2 hours.
312. (New) A method, comprising:
precipitating apatite from solution as an apatite precipitate; and
densifying the apatite precipitate into a densified article having a porosity of at least about 20%.

313. (New) The method of claim 312, wherein the article has an average XRD crystal size of less than about 250 nm.
314. (New) A method as in claim 312, wherein the step of precipitating comprises mixing a calcium source and a phosphate source.
315. (New) A method as in claim 312, further comprising the step of calcining the apatite precipitate at a temperature of less than about 1000 °C.
316. (New) A method as in claim 312, further comprising the step of allowing phase decomposition of less than about 10% in the densified article.
317. (New) A method as in claim 312, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
318. (New) An article, comprising:
an apatite structure having a density of at least about 98% and an average XRD crystal size of less than about 250 nm.
319. (New) The article of claim 318, wherein the apatite structure has a compressive strength of at least about 150 MPa.
320. (New) The article of claim 318, wherein the apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
321. (New) The article of claim 318, wherein the crystal size is less than about 150 nm.
322. (New) A method, comprising:
providing a composition comprising apatite; and

sintering the composition at a temperature of less than about 1100 °C to form a densified apatite structure having a density of at least 98%.

323. (New) The method of claim 322, wherein the sintered composition has a compressive strength of at least about 150 MPa.

324. (New) The method of claim 322, wherein the sintered composition undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

325. (New) A method as in claim 322, further comprising the step of calcining the composition at a temperature of less than about 1000 °C.

326. (New) A method as in claim 322, further comprising the step of allowing phase decomposition of less than about 10% in the densified apatite structure.

327. (New) The method of claim 322, wherein the sintered composition undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1100 °C for at least about 2 hours.

328. (New) A method as in claim 322, wherein the sintering step comprises sintering the composition in the presence of an auxiliary structural additive.

329. (New) A method, comprising:

precipitating from a solution particulate apatite having a surface area of at least about 40 m²/g and an average XRD crystal size of less than about 250 nm.

330. (New) The method of claim 329, further comprising the step of removing the solvent from the particulate apatite.

331. (New) The method of claim 329, wherein the average XRD crystal size is less than about 150 nm.
332. (New) A method as in claim 331, wherein the average XRD crystal size is less than about 100 nm.
333. (New) A method as in claim 332, wherein the average XRD crystal size is less than about 50 nm.
334. (New) A method as in claim 329, wherein the precipitating step comprises adding a calcium salt to a phosphate source.
335. (New) A method as in claim 329, wherein the solution comprises a calcium salt at a concentration of less than about 1 M.
336. (New) A method as in claim 335, wherein the solution comprises a calcium salt at a concentration of less than about 0.5 M.
337. (New) A method as in claim 329, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 2.1 M.
338. (New) A method as in claim 337, wherein the solution comprises a calcium salt at a concentration of between about 0.16 M and about 0.21 M.
339. (New) A method as in claim 329, wherein the solution comprises a calcium salt and a phosphate source in a molar ratio of about 10:6.
340. (New) A method as in claim 329, wherein the precipitating step comprises mixing a calcium source and a phosphate source.

341. (New) A method as in claim 329, wherein the precipitating step comprises adding a calcium source to a phosphate source at a rate of less than about 0.010 mol of calcium source per minute.
342. (New) A method as in claim 341, wherein the adding rate is less than about 0.007 mol calcium source per minute.
343. (New) A method as in claim 342, wherein the adding rate is less than about 0.005 mol calcium source per minute.
344. (New) A method as in claim 334, wherein the calcium source comprises CaNO_3 .
345. (New) A method as in claim 334, wherein the phosphate source comprises $(\text{NH}_4)_2\text{HPO}_4$.
346. (New) A method as in claim 329, wherein the solution has a pH of between about 7 and about 14.
347. (New) A method as in claim 346, wherein the solution has a pH of between about 11 and about 13.
348. (New) A method as in claim 329, wherein the particulate apatite has an average XRD crystal size of less than about 150 nm.
349. (New) A method as in claim 348, wherein the particulate apatite has an average XRD crystal size of less than about 100 nm.
350. (New) A method as in claim 349, wherein the particulate apatite has an average XRD crystal size of less than about 50 nm.
351. (New) A method as in claim 350, wherein the particulate apatite has an average XRD crystal size of less than about 20 nm.

352. (New) A method as in claim 329, wherein the particulate apatite has a surface area of at least about 60 m²/g.
353. (New) A method as in claim 352, wherein the particulate apatite has a surface area of at least about 100 m²/g.
354. (New) A method as in claim 353, wherein the particulate apatite has a surface area of at least about 150 m²/g.
355. (New) A method as in claim 329, further comprising the step of wet grinding the particulate apatite to form an apatite product.
356. (New) A method as in claim 329, further comprising the step of aging the particulate apatite at a temperature of between about -25 °C and about 100 °C.
357. (New) A method as in claim 356, wherein the temperature is between about 10 °C and about 50 °C.
358. (New) A method as in claim 357, wherein the temperature is about 20 °C.
359. (New) A method as in claim 329, further comprising aging the particulate apatite for at least about 1 minute.
360. (New) A method as in claim 329, further comprising calcining the particulate apatite at a temperature of less than about 1000 °C.
361. (New) A method as in claim 329, further comprising sintering the particulate apatite at a temperature of no more than about 1200 °C for a period of time of no more than about 2 hours.

362. (New) A method as in claim 361, wherein the sintering step occurs at a temperature of no more than about 1100 °C for a period of time of no more than about 2 hours.

363. (New) A method as in claim 362, wherein the sintering step occurs at a temperature of no more than about 1000 °C for a period of time of no more than about 2 hours.

364. (New) A method as in claim 363, wherein the sintering step occurs at a temperature of no more than about 900 °C for a period of time of no more than about 2 hours.

365. (New) A method as in claim 329, further comprising sintering the particulate apatite at least about 1000 °C for a period of time of at least about 2 hours while allowing phase decomposition of less than about 10%.

366. (New) A method as in claim 365, wherein the temperature is of at least about 1100 °C.

367. (New) A method as in claim 329, wherein the sintering step occurs in the absence of sintering aids.

368. (New) A method as in claim 329, wherein the particulate apatite has a dimension of at least about 0.5 cm.

369. (New) A method as in claim 329, wherein the solution comprises, in suspension, an auxiliary structural additive.

370. (New) The method of claim 369, wherein the article is a composite particulate apatite.

371. (New) The method of claim 369, wherein the article comprises particulate auxiliary structural additive.

372. (New) A method as in claim 369, wherein the precipitating step comprises essentially simultaneously co-precipitating the apatite and an auxiliary structural additive.

373. (New) A method as in claim 369, further comprising, following precipitation of an auxiliary additive, precipitating the apatite from the solution.
374. (New) A composition, comprising:
particulate apatite having an average particle size small enough that the composition can be sintered to a density of at least 98% at a temperature of less than about 1100 °C.
375. (New) The composition of claim 374, wherein the temperature is less than about 1000 °C.
376. (New) The composition of claim 374, wherein the particulate apatite can be sintered to form a densified apatite structure having a compressive strength of at least about 150 MPa.
377. (New) The composition of claim 374, wherein the particulate apatite can be sintered to form a densified apatite structure having a dimension of at least about 0.5 cm.
378. (New) The composition of claim 374, wherein the particulate apatite can be sintered to form a densified apatite structure having an average XRD crystal size of less than about 250 nm.
379. (New) The composition of claim 374, wherein the particulate apatite can be sintered to form a densified apatite structure that undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
380. (New) The composition of claim 374, wherein the particulate apatite can be sintered to form a densified apatite structure having a porosity of at least about 20%.

381. (New) The composition of claim 374, wherein the particulate apatite has a surface area of at least about 40 m²/g.

382. (New) A composition, comprising:
particulate apatite having an average apatite crystal size of less than 100 nm and a surface area of at least about 40 m²/g.

383. (New) The composition of claim 382, wherein the particulate apatite undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

384. (New) An article, comprising:
a densified apatite structure having a porosity of greater than about 20%, wherein the densified apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

385. (New) The article of claim 384, wherein the densified apatite structure is a prosthesis.

386. (New) The article of claim 384, wherein the densified apatite structure has a compressive strength of at least about 150 MPa.

387. (New) The article of claim 384, wherein the densified apatite structure has an average XRD crystal size of less than about 250 nm.

388. (New) The article of claim 384, wherein the densified apatite structure has a density of at least about 90%.

389. (New) The article of claim 387, wherein the average XRD crystal size is less than about 50 nm.

390. (New) A composition, comprising:
particulate apatite having a surface area of at least about 60 m²/g.
391. (New) The composition of claim 390, wherein the particulate apatite is a composite.
392. (New) The composition of claim 390, wherein the particulate apatite has an average particle size of less than about 1 μm.
393. (New) The composition of claim 390, wherein the particulate apatite undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
394. (New) A method, comprising:
providing a suspension; and
colloidally pressing the suspension to form an apatite structure.
395. (New) The method of claim 394, wherein the suspension is a sol.
396. (New) The method of claim 394, wherein the suspension includes a polymer.
397. (New) The method of claim 394, wherein the suspension includes a surfactant.
398. (New) The method of claim 394, wherein the apatite structure is sintered.
399. (New) The method of claim 394, wherein the apatite structure is a densified apatite structure.
400. (New) The method of claim 394, wherein the densified apatite structure has a density of greater than about 90%.

401. (New) The method of claim 394, wherein the apatite structure has a dimension of at least about 0.5 cm.
402. (New) The method of claim 394, wherein the apatite structure has a compressive strength of at least about 150 MPa.
403. (New) The method of claim 394, wherein the apatite structure has a porosity of at least about 20%.
404. (New) The method of claim 394, wherein the apatite structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
405. (New) The method of claim 394, wherein the apatite structure has an average XRD crystal size of less than about 250 nm.
406. (New) The method of claim 394, wherein the apatite structure is a prosthesis.
407. (New) The method of claim 394, further comprising sintering the apatite structure.
408. (New) A method as in claim 407, wherein the sintering step occurs at a temperature of no more than about 1300 °C.
409. (New) A method as in claim 408, wherein the temperature is no more than about 1200 °C.
410. (New) A method as in claim 409, wherein the temperature is no more than about 1100 °C.
411. (New) A method as in claim 410, wherein the temperature is no more than about 1000 °C.

412. (New) A method as in claim 411, wherein the temperature is no more than about 900 °C.

413. (New) The method of claim 402, wherein the apatite structure has a compressive strength of at least about 500 MPa.

414. (New) The method of claim 413, wherein the apatite structure has a compressive strength of at least about 700 MPa.

415. (New) A method as in claim 407, wherein the apatite structure has undergone apatite decomposition of less than about 10%.

416. (New) A method as in claim 415, wherein the apatite structure has undergone apatite decomposition of less than about 5%.

417. (New) A method as in claim 416, wherein the apatite structure has undergone apatite decomposition of less than about 3%.

418. (New) A composition, comprising:
_____ a densified apatite; and
_____ nanocrystalline zirconia.

419. (New) The composition of claim 418, wherein the composition has a compressive strength of at least about 150 MPa.

420. (New) The composition of claim 418, wherein the composition has a porosity of at least about 20%.

421. (New) The composition of claim 418, wherein the composition undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.

422. (New) The composition of claim 418, wherein the composition has an average XRD crystal size of less than about 250 nm.
423. (New) The composition of claim 418, wherein the composition has a surface area of at least about 40 m²/g.
424. (New) The composition of claim 418, wherein the composition has a density of at least about 90%.
425. (New) A method, comprising:
 providing a nanocrystalline apatite; and
 dispersing the nanocrystalline apatite in a zirconia suspension.
426. (New) The method of claim 425, further comprising the step of precipitating particulate apatite from the suspension.
427. (New) The method of claim 425, further comprising calcining the particulate apatite.
428. (New) The method of claim 425, further comprising sintering the particulate apatite.
429. (New) A method as in claim 427, wherein the calcining step occurs at a temperature of less than about 1000 °C.
430. (New) A method as in claim 428, wherein the sintering step occurs at a temperature of less than about 1200 °C for a period of time of at least about 2 hours.
431. (New) The method of claim 426, wherein the particulate apatite has a compressive strength of at least about 150 MPa.

432. (New) The method of claim 426, wherein the particulate apatite has a porosity of at least about 20%.
433. (New) The method of claim 426, wherein the particulate apatite undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.
434. (New) The method of claim 426, wherein the particulate apatite has an average XRD crystal size of less than about 250 nm.
435. (New) The method of claim 426, wherein the particulate apatite has a surface area of at least about 40 m²/g.
436. (New) The method of claim 426, wherein the particulate apatite is densified to at least about 90%.
437. (New) A composition, comprising:
_____ nanocrystalline apatite; and
_____ nanocrystalline zirconia.
438. (New) The composition of claim 437, wherein the composition has a compressive strength of at least about 150 MPa.
439. (New) The composition of claim 437, wherein the composition has a porosity of at least about 20%.
440. (New) The composition of claim 437, wherein the composition undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.

441. (New) The composition of claim 437, wherein the composition has an average XRD crystal size of less than about 250 nm.
442. (New) The composition of claim 437, wherein the composition has a surface area of at least about 40 m²/g.
443. (New) The composition of claim 437, wherein the composition has a density of at least about 90%.
444. (New) A method, comprising:
providing a composition comprising zirconia and an apatite; and
sintering the composition to produce a material having a density of at least about 98% wherein the apatite phase has undergone less than 10% decomposition.
445. (New) The method of claim 444, wherein the material has less than about 50% zirconia by volume.
446. (New) The method of claim 445, wherein the material has less than about 10% zirconia by volume.
447. (New) The method of claim 444, wherein the material has an average XRD crystal size of less than about 32 nm.
448. (New) The method of claim 444, wherein the material has an average surface area of greater than about 66.8 m²/g.
449. (New) The method of claim 444, wherein the material has a compressive strength of at least about 745 MPa.
450. (New) The method of claim 449, wherein the material has a compressive strength of at least about 1020 MPa.

451. (New) The method of claim 444, wherein the material has a dimension of at least about 0.5 cm.

452. (New) The method of claim 444, wherein the sintering step occurs at a temperature of less than about 1300 °C.

453. (New) The method of claim 452, wherein the temperature is less than about 1200 °C.

454. (New) The method of claim 453, wherein the temperature is less than about 1100 °C.

455. (New) The method of claim 444, further comprising the step of calcining the composition before the sintering step.

456. (New) The method of claim 455, wherein the calcining step occurs at a temperature of at least about 550 °C.

457. (New) A method, comprising:
_____ providing a composition comprising zirconia and an apatite; and
_____ sintering the composition to produce a material that undergoes phase
decomposition of less than about 10% when exposed to conditions of at least about 1300
°C for at least about 2 hours.

458. (New) A method as in claim 457, wherein the material has a compressive strength of at least about 745 MPa.

459. (New) The method of claim 457, wherein the material has less than about 50% zirconia by volume.

460. (New) The method of claim 459, wherein the material has less than about 10% zirconia by volume.

461. (New) The method of claim 457, wherein the material has an average XRD crystal size of less than about 32 nm.
462. (New) The method of claim 457, wherein the material has an average surface area of greater than about 66.8 m²/g.
463. (New) The method of claim 458, wherein the material has a compressive strength of at least about 1020 MPa.
464. (New) The method of claim 457, wherein the material has a dimension of at least about 0.5 cm.
465. (New) The method of claim 457, wherein the sintering step occurs at a temperature of less than about 1300 °C.
466. (New) The method of claim 465, wherein the temperature is less than about 1200 °C.
467. (New) The method of claim 466, wherein the temperature is less than about 1100 °C.
468. (New) The method of claim 457, further comprising the step of calcining the zirconia before the sintering step.
469. (New) The method of claim 468, wherein the calcining step occurs at a temperature of at least about 550 °C.
470. (New) A method, comprising:
_____ providing zirconia and an apatite; and
_____ mixing the zirconia and the apatite to produce a homogeneous material.

471. (New) A method as in claim 470, wherein the zirconia has a crystal size of less than about 32 nm.
472. (New) The method of claim 470, wherein the material has less than about 50% zirconia by volume.
473. (New) The method of claim 472, wherein the material has less than about 10% zirconia by volume.
474. (New) The method of claim 470, wherein the material has an average surface area of greater than about 66.8 m²/g.
475. (New) The method of claim 470, wherein the material has a compressive strength of at least about 745 MPa.
476. (New) The method of claim 475, wherein the material has a compressive strength of at least about 1020 MPa.
477. (New) A method, comprising:
providing a solution comprising zirconia particles and an apatite, wherein the zirconia particles are dispersed in solution;
precipitating an apatite precipitant from the solution.
478. (New) A method as in claim 477, wherein the material has an average XRD crystal size of less than about 250 nm.
479. (New) A method as in claim 478, wherein the material has a crystal size of less than about 32 nm.
480. (New) The method of claim 477, wherein the material has less than about 50% zirconia by volume.

481. (New) The method of claim 480, wherein the material has less than about 10% zirconia by volume.
482. (New) The method of claim 477, wherein the material has an average surface area of greater than about 66.8 m²/g.
483. (New) The method of claim 477, wherein the material has a compressive strength of at least about 745 MPa.
484. (New) The method of claim 483, wherein the material has a compressive strength of at least about 1020 MPa.
485. (New) A method, comprising:
providing a solution comprising zirconia particles and an apatite, wherein the zirconia particles are dispersed in solution; and
aging the solution.
486. (New) A method, comprising:
providing a composite of zirconia and an apatite; and
calcining the composite to produce a material having a surface area of at least about 66.8 m²/g.
487. (New) A method as in claim 486, wherein the material has a crystal size of less than about 32 nm.
488. (New) The method of claim 486, wherein the material has less than about 50% zirconia by volume.
489. (New) The method of claim 488, wherein the material has less than about 10% zirconia by volume.

490. (New) The method of claim 486, wherein the material has a compressive strength of at least about 745 MPa.

491. (New) The method of claim 490, wherein the material has a compressive strength of at least about 1020 MPa.

492. (New) An article, comprising:
a structure comprising zirconia and apatite, the structure formed from particles having an average XRD crystal size of less than about 250 nm.

493. (New) The article of claim 492, wherein the structure is a homogenous mixture.

494. (New) The article of claim 492, wherein the crystal size is less than about 32 nm.

495. (New) The article of claim 492, wherein the structure has a compressive strength of at least about 150 MPa.

496. (New) The article of claim 492, wherein the structure has a porosity of at least about 20%.

497. (New) The article of claim 492, wherein the structure undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.

498. (New) The article of claim 492, wherein the structure has a density of at least about 90%.

499. (New) The article of claim 492, wherein the structure has a surface area of at least about 66.8 m²/g.

500. (New) An article, comprising:
a structure comprising zirconia and apatite, the structure formed from particles
having a surface area of at least about 66.8 m²/g.
501. (New) The article of claim 500, wherein the structure is a homogenous mixture.
502. (New) The article of claim 500, wherein the structure has a compressive strength of at
least about 150 MPa.
503. (New) The article of claim 500, wherein the structure has an average XRD crystal size of
less than about 250 nm.
504. (New) The article of claim 500, wherein the structure has a porosity of at least about
20%.
505. (New) The article of claim 500, wherein the structure undergoes phase decomposition of
less than about 10% when exposed to conditions of at least about 1000 °C for at least
about 2 hours.
506. (New) The article of claim 500, wherein the structure has a density of at least about 90%.
507. (New) A method, comprising co-precipitating zirconia and an apatite from a solution.
508. (New) The method of claim 507, wherein the zirconia is nanocrystalline.
509. (New) The method of claim 507, wherein the apatite is nanocrystalline.
510. (New) A method, comprising:
providing an apatite precipitate; and
dispersing zirconia in the apatite precipitate.

511. (New) The method of claim 510, wherein the apatite precipitate is nanocrystalline.
512. (New) The method of claim 510, wherein the zirconia is nanocrystalline.
- 513 (New) An article, comprising nanocrystalline carbonated apatite.
514. (New) The article of claim 513, wherein the carbonated apatite comprises Type A carbonated apatite.
515. (New) The article of claim 513, wherein the carbonated apatite comprises Type B carbonated apatite.
516. (New) The article of claim 513, wherein the nanocrystalline carbonated apatite has a compressive strength of at least about 150 MPa.
517. (New) The article of claim 513, wherein the nanocrystalline carbonated apatite has an average XRD crystal size of less than about 250 nm.
518. (New) The article of claim 513, wherein the nanocrystalline carbonated apatite has a porosity of at least about 20%.
519. (New) The article of claim 513, wherein the nanocrystalline carbonated apatite has a surface area of at least about 40 m²/g.
520. (New) The article of claim 513, wherein the nanocrystalline carbonated apatite undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.
521. (New) An method, comprising:
_____ providing a calcium salt and a phosphate salt; and

reacting CO₂ with the calcium salt and the phosphate salt to produce a nanocrystalline carbonated apatite.

522. (New) An method, comprising:

providing a calcium salt; and

reacting CO₂ with the salt to produce a nanocrystalline carbonated apatite.

523. (New) The method of claim 522, wherein the carbonated apatite has a compressive strength of at least about 150 MPa.

524. (New) The method of claim 522, wherein the carbonated apatite has a porosity of at least about 20%.

525. (New) The method of claim 522, wherein the carbonated apatite undergoes phase demethod of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.

526. (New) The method of claim 522, wherein the carbonated apatite has an average XRD crystal size of less than about 250 nm.

527. (New) The method of claim 522, wherein the carbonated apatite has a surface area of at least about 40 m²/g.

528. (New) The method of claim 522, wherein the carbonated apatite has a density of at least about 90%.

529. (New) A method, comprising:

providing a calcium salt and a phosphate salt; and

reacting NH₄HCO₃ with the calcium salt and the phosphate salt to produce a nanocrystalline carbonated apatite.

530. (New) A method, comprising:
_____ providing a calcium salt; and
_____ reacting NH_4HCO_3 with the salt to produce a nanocrystalline carbonated apatite.
531. (New) The method of claim 530, wherein the carbonated apatite has a compressive strength of at least about 150 MPa.
532. (New) The method of claim 530, wherein the carbonated apatite has a porosity of at least about 20%.
533. (New) The method of claim 530, wherein the carbonated apatite undergoes phase demethod of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.
534. (New) The method of claim 530, wherein the carbonated apatite has an average XRD crystal size of less than about 250 nm.
535. (New) The method of claim 530, wherein the carbonated apatite has a surface area of at least about 40 m²/g.
536. (New) The method of claim 530, wherein the carbonated apatite has a density of at least about 90%.
537. (New) A composition, comprising:
_____ carbonated apatite having a surface area of at least 40 m²/g and an average XRD crystal size of less than about 250 nm.
538. (New) The composition of claim 537, wherein the carbonated apatite has a compressive strength of at least about 150 MPa.

539. (New) The composition of claim 537, wherein the carbonated apatite has a porosity of at least about 20%.
540. (New) The composition of claim 537, wherein the carbonated apatite undergoes phase decomposition of less than about 10% when exposed to conditions of at least about 1000 °C for at least about 2 hours.
541. (New) A method, comprising:
providing a composition comprising apatite particles having a dimension of less than about 1 μm and crystal size of less than about 1 μm ; and
sintering the composition to form a densified apatite structure having an average XRD crystal size of less than about 250 nm, a density of at least about 98%, and a compressive strength of at least about 500 MPa, wherein the densified apatite structure undergoes apatite phase decomposition of less than about 10% when exposed to conditions of at least about 1300 °C for at least about 2 hours.
542. (New) A composition, comprising particulate apatite having an average apatite crystal size of less than 100 nm and a surface area greater 60 m^2/g .
543. (New) The composition of claim 542 comprising particulate apatite having an average apatite crystal size of less than 50 nm.
544. (New) The composition of claim 543 comprising particulate apatite having an average apatite crystal size of less than 30 nm.
545. (New) The composition of claim 544 comprising particulate apatite having an average apatite crystal size of less than 20 nm.
546. (New) A composition as in claim 542 wherein the particulate apatite is densified.

547. (New) The composition of claim 542 comprising apatite having an average particle size of less than 1 μm .
548. (New) The composition of claim 547 comprising apatite having an average particle size of less than 0.5 μm .
549. (New) The composition of claim 548 comprising apatite having an average particle size of less than 0.25 μm .
550. (New) The composition of claim 542 comprising particulate apatite having a surface area of at least 100 m^2/g .
551. (New) The composition of claim 550 comprising particulate apatite having a surface area of at least 150 m^2/g .
552. (New) The composition of claim 542 that undergoes apatite phase decomposition of less than 10% when exposed to conditions of at least 1000 $^{\circ}\text{C}$ for at least 2 hours.
553. (New) The composition of claim 552 that undergoes apatite phase decomposition of less than 5% when exposed to conditions of at least 1000 $^{\circ}\text{C}$ for at least 2 hours.
554. (New) The composition of claim 553 that undergoes apatite phase decomposition of less than 3% when exposed to conditions of at least 1000 $^{\circ}\text{C}$ for at least 2 hours.
555. (New) The composition of claim 552 that undergoes apatite phase decomposition of less than 10% when exposed to conditions of at least 1100 $^{\circ}\text{C}$ for at least 2 hours.
556. (New) The composition of claim 555 that undergoes apatite phase decomposition of less than 5% when exposed to conditions of at least 1100 $^{\circ}\text{C}$ for at least 2 hours.

557. (New) The composition of claim 556 that undergoes apatite phase decomposition of less than 3% when exposed to conditions of at least 1100 °C for at least 2 hours.
558. (New) The composition of claim 552 that undergoes apatite phase decomposition of less than 10% when exposed to conditions of at least 1200 °C for at least 2 hours.
559. (New) The composition of claim 558 that undergoes apatite phase decomposition of less than 5% when exposed to conditions of at least 1200 °C for at least 2 hours.
560. (New) The composition of claim 559 that undergoes apatite phase decomposition of less than 3% when exposed to conditions of at least 1200 °C for at least 2 hours.
561. (New) The composition of claim 552 that undergoes apatite phase decomposition of less than 10% when exposed to conditions of at least 1300 °C for at least 2 hours.
562. (New) The composition of claim 561 that undergoes apatite phase decomposition of less than 5% when exposed to conditions of at least 1300 °C for at least 2 hours.
563. (New) The composition of claim 562 that undergoes apatite phase decomposition of less than 3% when exposed to conditions of at least 1300 °C for at least 2 hours.
564. (New) An article having a dimension of at least 0.5 cm made up of the composition of claim 542.
565. (New) The article of claim 564 wherein the particulate apatite is consolidated.
566. (New) The article of claim 564, formed into the shape of a prosthesis.
567. (New) The article of claim 564 that is a prosthesis.
568. (New) The article of claim 564 comprising an exterior coating on a prosthesis.

569. (New) The article of claim 568 comprising an exterior coating, on a prosthesis, of at least 0.5 μm in thickness.
570. (New) The article of claim 564 having a density of at least 90%.
571. (New) The article of claim 570 having a density of at least 95%.
572. (New) The article of claim 571 having a density of at least 98%.
573. (New) The article of claim 564 having a porosity of at least 20%.
574. (New) The article of claim 573 having a porosity of at least 30%.
575. (New) The article of claim 574 having a porosity of at least 50%.
576. (New) The article of claim 575 having a porosity of at least 75%.
577. (New) The article of claim 564 having compressive strength of at least about 150 MPa.
578. (New) The article of claim 577 having compressive strength of at least about 500 MPa.
579. (New) The article of claim 578 having compressive strength of at least about 700 MPa.
580. (New) The article of claim 564 that is a part of a prosthesis.

REMARKS

The present application is an application for reissue of U.S. Patent No. 6,013,591, granted on January 11, 2000. Claims 1-44 in the present application (filed herewith) are identical to claims 1-44 of U.S. Patent No. 6,013,591. New claims 45-580 are being added with this preliminary amendment. No new matter has been added. Claims 1-580 are now pending in the present application.

CONCLUSION


A favorable first Office Action is respectfully requested.

If, for any reason, the Examiner is of the opinion that a telephone conversation with Applicants' representative would expedite prosecution, the Examiner is kindly invited to contact the undersigned at (617) 720-3500.

Please charge any fee or fee deficiency occasioned by this amendment to Deposit Account No. 23/2825.

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